VEGETATION OF THE BALD HILLS OAK WOODLANDS, REDWOOD NATIONAL PARK, CALIFORNIA

Neil G. Sugihara and Lois J. Reed
Redwood National Park, P.O. Box 7, Orick, CA 95555

James M. Lenihan
Department of Geography, Oregon State University, Corvallis 97331

Abstract

Composition and structure are determined for stands of bald hills *Quercus garryana* (Oregon white oak) woodland in Redwood National Park, California. Seven distinct plant community types are found. Distribution of the three most widespread types is related to moisture, slope position, and fire history: 1) *Quercus/Cynosurus* (xeric woodlands); 2) *Quercus/Dactylis* (mesic woodlands); and 3) *Quercus/Symphoricarpos* (dense, young mesic stands). Four types occupy specific habitats within the park: 4) *Ribes/Phacelia* (rock outcrops); 5) *Arrhenatherum/Sherardia* (glades); 6) *Quercus/Delphinium* (seasonally moist areas within xeric woodlands); and 7) *Philadelphus/Cystopteris* (stream channels).

Quercus garryana Dougl. (Oregon white oak) ranges from British Columbia to the Santa Cruz Mountains of California (Griffin and Critchfield 1972). Optimum development is reached in the Willamette Valley of Oregon, where *Q. garryana* dominates oak woodlands that occupy over 400,000 ha (Franklin and Dyrness 1973). In the North Coast Ranges of California, *Q. garryana* dominates the northern oak woodland and is a minor component of several forest types. The northern oak woodland consists of two distinct elements, a continuation of the interior foothill woodland and a coastal community type that is structurally distinct and known as "bald hills" oak woodlands (Griffin 1977).

Bald hills oak woodlands occur in the Coast Ranges of California from Humboldt and Trinity cos., southward to Napa Co. Approximately 19% of this area supports oak or oak-grassland vegetation (Wieslander and Jensen 1948, Storie and Wieslander 1952). Although the woodlands occur between 75–1600 m elevation throughout the region, they are best developed along ridgetops and upper south-facing slopes in Humboldt and Mendocino cos. The bald hills oak woodlands are structurally distinguished by a patchy mosaic pattern of dominance by either oak or grasses and not the balanced mixture of oaks and grassland found elsewhere in California (Clark 1937).

Thilenius (1968) describes the vegetation of Willamette Valley oak woodlands as seral and derived from open oak savannahs by

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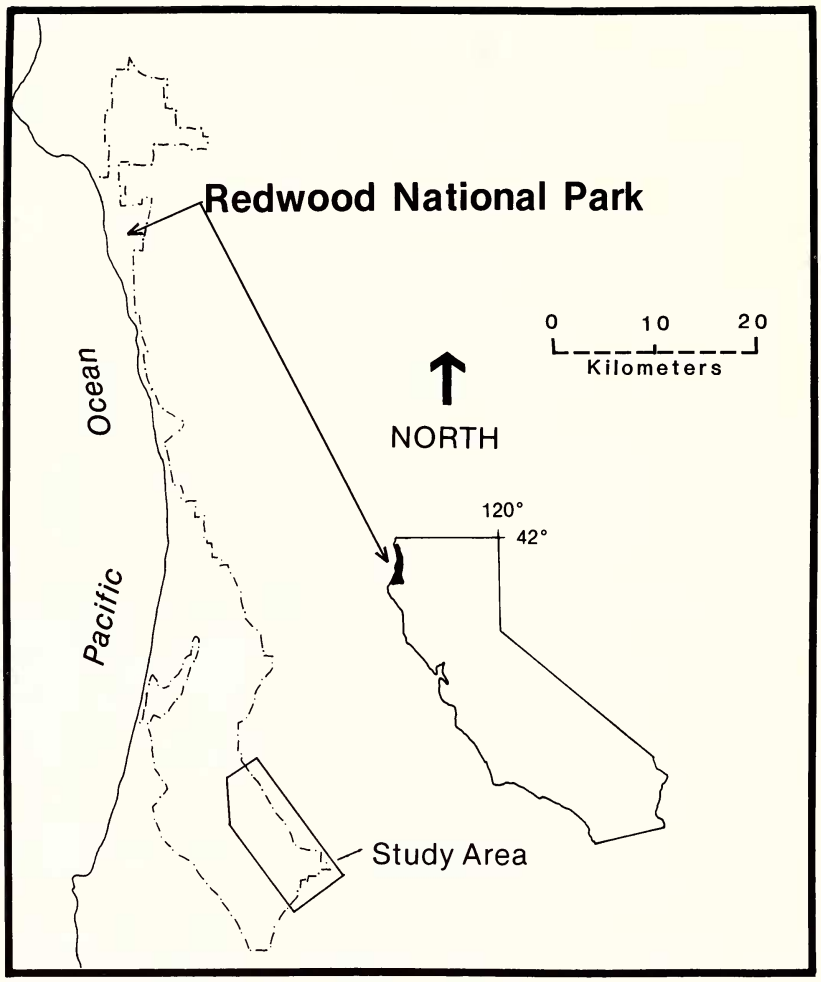

FIG. 1. Location of the study area within Redwood National Park and California.

the exclusion of fire. He defines four plant communities primarily by their shrub layers. Sugihara et al. (1983) found three stand structural types in the oak woodlands of Redwood National Park (RNP): 1) open savannah stands composed of all size classes and dominated by a few, large, widely scattered individuals; 2) closed-canopy stands of numerous, uniformly medium-sized, clustered trees; and 3) dense closed-canopy stands with uniformly small, single-stemmed individuals. Hektner et al. (1983) describe the vegetation composition and dynamics after disturbance of the open bald hills grassland outside the oak-grass mosaic. No other studies describe the flora or vegetation succession of the coastal bald hills. The purpose of this

FIG. 2. A view, looking northwest from Schoolhouse Peak, of the oak/grass mosaic and study area. Best development of the woodland is near the ridges, with redwood forests downslope.

study is to describe and classify the present vegetation in the northern range of the bald hills oak woodlands. Results of this study of present conditions will contribute to the potential for restoration and maintenance of the woodlands as a natural ecosystem. These baseline data will help assess the effects of the future management of the ecosystem.

STUDY AREA

Location. The 250 ha study area (Figs. 1, 2) is located within the Redwood Creek basin of RNP in Humboldt Co. and is representative of the northern extent of the bald hills oak woodlands. The area lies 8–22 km from the coast and 85–95 km south of the Oregon border. Redwood Creek flows from the southeast to the northwest and empties into the ocean at Orick, California. The grassland/woodland mosaic ranges in elevation from the banks of Redwood Creek (75 m) to near the top of Schoolhouse Peak (945 m) on the northeast slope above Redwood Creek.

Climate. Regional climate is Mediterranean, with strong oceanic influence at lower elevations in the northwest portion of the study area where summer fog frequently occurs. Approximately 90% of the total annual precipitation falls between October and May. Average annual rainfall ranges between 178 cm and 203 cm with snow

rarely falling except at higher elevations (Coghlan 1984). The mean daily maximum temperature in July is 25°C with absolute maxima rarely exceeding 38°C. The mean daily minimum in January is 2°C. Absolute minima rarely go below −7°C (Humboldt State Univ. 1974).

Geology and soils. Geologic substrate of the study area is residuum and colluvium from Franciscan siltstone, sandy siltstone, and graywacke sandstone. The landscape is characterized by numerous earthflows. A complex pattern of Inceptisol, Alfisol, and Ultisol soils underlies the woodlands, adjacent forests, and grasslands. Subsoil properties largely reflect geologic substratum and relief. Forest soils lack the umbric epipedon found in woodland and prairie soils, but all of these subsoils have a similar range of properties. Consistent soil patterns that correspond with forest/woodland/grassland boundaries have not been established (J. Popenoe pers. comm.).

Historical use. Native Americans regularly set fire to the bald hills for at least 6000 years prior to 1864, and these fires profoundly affected vegetation patterns (Thompson 1916, Lewis 1973, Bickel 1979, King and Bickel 1980, Benson 1983, Hayes 1985). Livestock grazing that was initiated by European settlers resulted in the establishment of many aggressive, non-native range plants, and was discontinued by the National Park Service in 1982. Extensive logging of adjacent redwood and Douglas-fir forests has been the primary disturbance factor affecting vegetation in the Redwood Creek basin from the 1940's until acquisition by the Park Service in 1978.

Methods

Field reconnaissance of the study area revealed several plant assemblages within the oak woodland with distinct structure and composition. These assemblages were sampled by placing a total of 56 relevé plots averaging 750 m in homogeneous vegetation within uniform habitats (Mueller-Dombois and Ellenberg 1974). A list of all vascular plant species in each plot was compiled by height strata. Visual estimates of cover for the canopy, shrub, and herbaceous layers, as well as of each species, were made using the Braun-Blanquet (1932) cover scale: 1 = <1–5%, 2 = 5–25%, 3 = 25–50%, 4 = 50–75%, 5 = 75–100%. Aspect, slope, slope position, topographic configuration, oak stand type, exposure, and elevation of each plot also were recorded. Sampling was completed from May–July 1983, which coincides with the flowering and fruiting periods of most species. Nomenclature generally follows Munz (1973). Voucher specimens are on file at RNP.

Floristic characterization is based on species cover, percent occurrence, and fidelity. The stand classification is interpreted at a division level where the stand groups best represented the vegetation

TABLE 1. SYNOPTIC TABLE OF HIGH PRESENCE SPECIES IN OAK WOODLANDS BY VEGETATION TYPE. All species with less than 0.50 presence within the type are omitted. The first figure is the modal cover for each species found in the plots, based on Braun-Blanquet (1932). The second figure is the species presence for all plots within each vegetation type. Qu/Sy = *Quercus/Symphoricarpos*, Qu/Da = *Quercus/Dactylis*, Qu/De = *Quercus/Delphinium*, Ph/Cy = *Philadelphus/Cystopteris*, Ri/Ph = *Ribes/Phacelia*, Qu/Cy = *Quercus/Cynosurus*, Ar/Sh = *Arrhenatherum/Sherardia*. N = native species, I = introduced species.

Life form Species	Vegetation types (number of plots)						
	Qu/Sy (9)	Qu/Da (12)	Qu/De (12)	Ph/Cy (4)	Ri/Ph (4)	Qu/Cy (6)	Ar/Sh (9)
Trees							
Pseudotsuga menziesii (N)	1-0.89	1-0.75	1-0.58			1-0.50	
Acer macrophyllum (N)				1-1.00			
Quercus garryana (N)							
Seedlings	2-1.00	1-0.92	1-1.00	1-1.00	1-1.00	1-1.00	
Trees	5-1.00	5-1.00	5-1.00	4-1.00	3-1.00	5-1.00	
Shrubs							
Symphoricarpos rivularis (N)	2-1.00			1-1.00	1-0.75		
Rhus diversiloba (N)	1-1.00	1-0.92			2-1.00	1-0.67	
Holodiscus discolor (N)				2-1.00	2-0.75		
Philadelphus lewisii (N)				3-1.00	3-0.50		
Ribes roezlii (N)	1-0.56				2-1.00		
Rosa pisocarpa (N)				1-1.00	1-0.50		
Amelanchier pallida (N)				1-0.75			
Osmaronia cerasiformis (N)				1-1.00			
Rubus vitifolius (N)	1-0.89			2-0.50	1-0.50	1-0.50	
Grasses							
Trisetum cernuum (N)	1-0.89	1-0.58	1-0.58	1-0.50			
Dactylis glomerata (I)	1-0.89	2-1.00	1-0.75	1-0.50	1-0.50	1-0.83	
Melica subulata (N)	1-1.00	2-1.00	2-0.92	1-1.00		2-0.67	1-0.67

TABLE 1. CONTINUED.

Life form Species	Vegetation types (number of plots) Qu/Sy (9)	Qu/Da (12)	Qu/De (12)	Ph/Cy (4)	Ri/Ph (4)	Qu/Cy (6)	Ar/Sh (9)
Bromus carinatus (N)	2-1.00	1-1.00	1-0.92	1-0.50	1-0.50	1-0.50	2-0.67
Bromus sterilis (I)			1-0.83		1-0.75	1-1.00	
Elymus glaucus (N)	1-1.00	1-1.00	2-1.00	1-1.00	2-0.75	2-1.00	1-1.00
Avena barbata (I)					1-1.00		
Agrostis hallii (N)	1-1.00	1-0.58	1-0.50	1-0.50		1-1.00	1-0.78
Cynosurus echinatus (I)	1-0.56	1-1.00	1-0.92	1-1.00	1-1.00	3-1.00	2-1.00
Poa pratensis (I)	1-0.56		1-0.75			2-1.00	1-0.89
Holcus lanatus (I)	1-0.89	1-0.50	1-0.58	1-0.75		2-1.00	2-1.00
Arrhenatherum elatius (I)		1-0.58	1-0.83	1-0.50	1-0.75	2-1.00	3-1.00
Bromus rigidus (I)					2-1.00	1-0.67	1-0.67
Festuca viridula (N)			1-0.67		1-0.75		2-0.89
Aira caryophyllea (I)					1-0.50		1-0.89
Bromus mollis (I)						1-0.50	1-1.00
Ferns							
Polystichum munitum (N)	2-0.89		1-0.58	1-0.75	1-0.50		
Cystopteris fragilis (N)				1-1.00			
Cheilanthes gracillima (N)					1-1.00		
Polypodium glycyrrhiza (N)				1-0.75			
Pteridium aquilinum (N)					1-1.00		3-0.56
Forbs							
Galium nuttallii (N)		1-0.92					
Satureja douglasii (N)	3-1.00	2-0.92					
Polygala californica (N)		1-0.50					

TABLE 1. CONTINUED.

Life form Species	Vegetation types (number of plots) Qu/Sy (9)	Qu/Da (12)	Qu/De (12)	Ph/Cy (4)	Ri/Ph (4)	Qu/Cy (6)	Ar/Sh (9)
Ligusticum apiifolium (N)	1-1.00		1-0.50				
Fragaria californica (N)	2-1.00	1-1.00		1-0.50		1-0.50	
Chlorogalum pomeridianum (N)	1-0.78	1-0.83		1-0.50	1-0.75		
Cynoglossum grande (N)	1-0.89						
Lathyrus vestitus (N)	1-0.67	2-0.67	1-0.58	1-1.00			
Phacelia heterophylla (N)					2-1.00		
Circaea alpina (N)	1-0.56			1-1.00			
Claytonia perfoliata (N)	1-0.78		2-1.00	1-0.75	1-1.00		
Trillium chloropetalum (N)	1-1.00		1-0.50	1-1.00			
Silene californica (N)				1-0.50	1-1.00		
Delphinium trolliifolium (N)			4-0.83	2-1.00	2-0.50		1-0.56
Galium aparine (I)	1-1.00	1-0.92	2-1.00	1-1.00	2-1.00	1-1.00	
Osmorhiza chilensis (N)	1-0.89	2-1.00	1-1.00	1-1.00	1-0.50	1-1.00	
Sanicula crassicaulis (N)	1-1.00	2-1.00	1-0.92	2-1.00	1-1.00	2-1.00	
Brodiaea ida-maia (N)	1-1.00	1-0.67	1-0.67	1-0.50	1-1.00	1-0.50	1-0.78
Vicia americana (N)	1-0.89	2-0.83	1-0.92	1-0.50	1-0.50	1-0.83	1-0.67
Cerastium arvense (N)	1-0.89						
Caucalis microcarpa (N)		1-0.92	1-0.58	1-1.00	2-1.00	1-0.67	1-0.89
Marah oreganus (N)	1-1.00		1-0.75	1-1.00	1-1.00	1-0.50	1-1.00
Ranunculus occidentalis (N)		1-0.83	1-0.92	1-0.75	1-0.50	1-0.83	1-0.89
Taraxacum officinale (I)			1-0.50	1-0.50		1-1.00	
Hypochoeris radicata (I)			1-0.50		1-1.00	1-1.00	1-0.67
Cirsium vulgare (I)		1-0.50				1-0.83	1-1.00
Plantago lanceolata (I)		1-0.75		1-0.50		1-1.00	1-1.00
Rumex acetosella (I)			1-0.75		1-1.00	3-1.00	2-1.00
Sherardia arvensis (I)							1-0.89

types observed in the field. One-hundred thirty-five species with frequencies greater than 5% were entered into TWINSPAN, a computer analysis procedure in the Cornell Ecology Program (CEP) series (Hill 1979a). TWINSPAN is a program for two-way indicator species analysis, a polythetic divisive method for community classification. The program was run with all default options except for the definition of pseudospecies cut-levels. Four cut-levels were defined as follows: level 1 = 1–5% cover, level 2 = 6–25% cover, level 3 = 26–50% cover, and level 4 = 51–100% cover.

The classified stands and 135 species are ordinated by detrended correspondence analysis using the DECORANA program in the CEP series (Hill 1979b) to reveal any additional dimension of the stand-group relationship. The DECORANA procedure was run with all default values and options. Comparisons of physiographic data with distribution of community types on the ordination graph and field observations produced environmental interpretations of plant community relationships. Plant community descriptions were then developed and used to classify and map the vegetation within the study area.

Results

Three-hundred five species were found during sampling. Analysis by TWINSPAN identified seven plant communities with three distinct structural forms: tree-dominated, shrub-dominated, and grass-dominated (Table 1). Four communities contain *Q. garryana* as the main structural unit. Two communities have shrubs composing the main structural unit with some *Q. garryana* present. The other community is dominated by grasses with mature *Q. garryana* absent. Within each life form category, species are ordered by relationships to one another. In general, species with mesic habitats are followed by those occurring in more xeric habitats. The distribution of the classified stands in floristic ordination space is shown in Fig. 3. Environmental features of the areas supporting the seven vegetation types are presented in Table 2.

Descriptions of the plant communities are based on Tables 1 and 2. Vegetation types are named for a combination of two species. The first is a dominant member of the main structural element. The second is a characteristic species with high cover and presence. The names reflect the mosaic pattern where oaks are either dominant or nearly absent. Important associates are species with high modal cover and presence.

Quercus/Symphoricarpos (Qu/Sy): This woodland type is found mid-slope in uniform, extremely dense stands of 25–40 yr-old, small-diametered oaks. *Symphoricarpos rivularis* forms most of the well developed low shrub layer. This type has the densest understory with the greatest number of shrub species and highest shrub cover

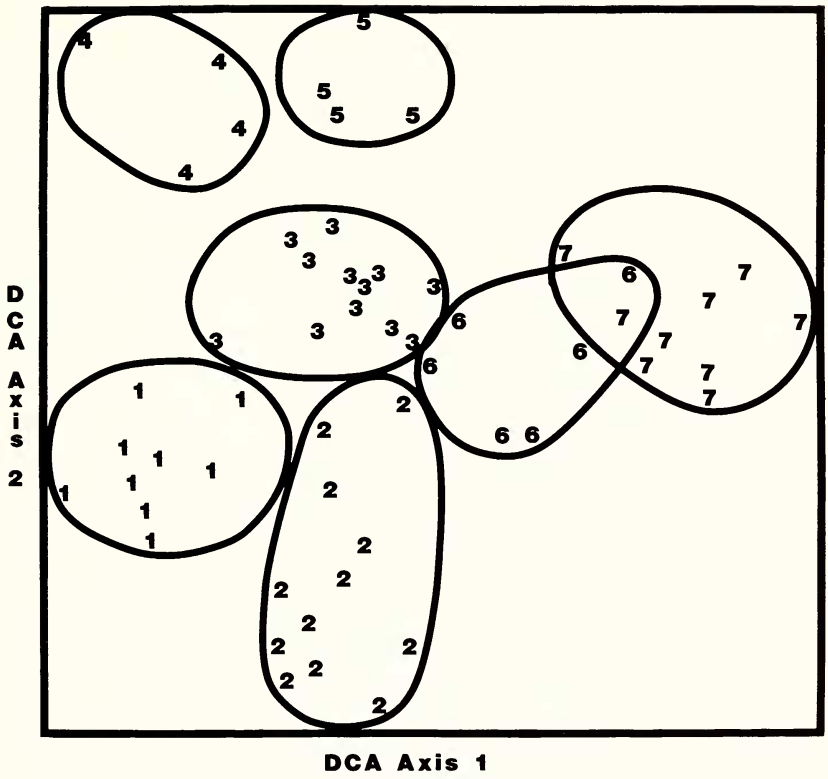

FIG. 3. Ordination graph showing the floristic relationships between plots. 1 = *Quercus/Symphoricarpos*, 2 = *Quercus/Dactylis*, 3 = *Quercus/Delphinium*, 4 = *Philadelphus/Cystopteris*, 5 = *Ribes/Phacelia*, 6 = *Quercus/Cynosurus*, 7 = *Arrhenatherum/Sherardia*.

(30%) of any oak-dominated type. Forbs dominate the herbaceous layer with only scattered grasses present. Important associates in the perennial forb-dominated herb layer include *Polystichum munitum, Satureja douglasii, Fragaria californica,* and *Bromus carinatus. Ligusticum apiifolium, Rubus vitifolius, Cynoglossum grande, Cerastium arvense,* and *Festuca occidentalis* are the more commonly encountered species that characterize this type.

Quercus/Dactylis (Qu/Da): This mesic woodland type is extensive on lower concave slopes associated with uniform, medium-sized oak stands. A mixture of tall, perennial grasses and perennial forbs dominates the understory. The shrub layer is very sparse. Important associates include *Dactylis glomerata, S. douglasii, Osmorhiza chilense, F. californica, Sanicula crassicaulis,* and *Vicia americana. Galium nuttallii, Lonicera hispidula,* and *Stachys rigida* are common characteristic species.

TABLE 2. GENERAL CHARACTERISTICS OF OAK WOODLAND VEGETATION TYPES. Acronyms are listed in Table 1. [1] = Whittaker (1960); [2] = Sugihara et al. (1983).

Characteristic	Vegetation types						
	Qu/Sy	Qu/Da	Qu/De	Ph/Cy	Ri/Ph	Qu/Cy	Ar/Sh
Mean plot elevation (m)	710	250	785	755	785	715	750
Mean slope (%)	30	35	35	35	30	25	35
Typical exposure	WNW	SW	W	W	WSW	S	NW
Mean Whittaker moisture index[1]	7	5	8	1	8	8	7
Typical slope position	mid	lower	upper	upper	upper	upper	mid
Typical topographic configuration	even	concave	concave	concave	convex	convex	concave/ convex
Typical stand type[2]	dense	clustered	clustered	all	savannah	savannah	absent
Oak density (stems/ha)[2]	4500–12,000	740–2500	740–2500	variable	60–530	60–530	0
Mean canopy cover (%)	83	87	82	53	49	87	0
Mean shrub cover (%)	30	1	1	85	55	1	0
Mean herbaceous cover (%)	84	69	84	50	35	91	96
Mean number of species per plot	48	43	38	52	51	44	38
Native high presence species (% of total)	85	74	68	82	75	53	50

Quercus/Cynosurus (Qu/Cy): This xeric woodland type is dominated by shorter perennial and annual grasses with forb cover relatively low. The shrub layer is not well developed. This xeric type was the most heavily disturbed by grazing and occupies the upper, convex, south-facing slopes with oak stands containing a wide range of sizes and ages. Important associates include *Cynosurus echinatus, Holcus lanatus, Elymus glaucus, Poa pratensis, Arrhenatherum elatius, S. crassicaulis. Taraxacum officinale* is the most common characteristic species.

Quercus/Delphinium (Qu/De): Found on upper, concave slopes in uniform, medium-diametered oak stands, this type is restricted to concave topography on otherwise xeric slopes. In the spring and early summer, perennial forbs heavily dominate the understory of this distinctive woodland type. Forbs die back and grasses become dominant as the soil dries by mid-July, but the shrub layer remains sparse. *Delphinium trolliifolium* is the strong, early season dominant and *Dentaria californica, Lithophragma affine, Claytonia perfoliata,* and *Isopyrum stipitatum* are characteristic early season species. Important late season associates include *Galium aparine, Melica subulata,* and *E. glaucus.*

Arrhenatherum/Sherardia (Ar/Sh): Open glades dominated by perennial and annual grasses are found as narrow openings running up the slope within the oak stands. Shrubs are present only in scattered patches. These glades and the surrounding oaks form the distinctive oak/grass mosaic characteristic of the bald hills oak woodlands. Important associates include *A. elatius, H. lanatus, Festuca viridula, C. echinatus,* and *Rumex acetosella. Sherardia arvense, Lotus micranthus, Viola praemorsa, Aira caryophyllea,* and *Bromus mollis* are the common characteristic species. All of these species also are components of the open bald hills prairies. Many of the more abundant woodland species, however, such as *G. aparine, O. chilensis,* and *S. crassicaulis,* are absent from the Ar/Sh type.

Philadelphus/Cystopteris (Ph/Cy): This rocky stream channel type is composed of a dense shrub layer and a scattered herb layer of perennial forbs. The oak canopy is composed of a variety of stand types that range from very dense, small-diametered to large, broadly branched individuals. Canopy trees are found on the banks above the incised stream channels with their crowns extending over the channel but not rooted in the channel. *Philadelphus lewisii* and *Holodiscus discolor* dominate the tallest shrub layer found in these bald hills oak woodlands, and often reach a height of 7 m. *Sanicula crassicaulis* and *D. trolliifolium* are important associates in the herb layer. Characteristic shrubs include *Rosa pisocarpa, Amelanchier pallida,* and *Osmaronia cerasiformis. Cystopteris fragilis, Polypodium glycyrrhiza,* and *Tellima grande* are characteristic members of the herb layer.

Ribes/Phacelia (Ri/Ph): This rock outcrop type is composed of a moderately dense shrub layer and a scattered herb layer of perennial and annual forbs and grasses. The oak canopy is generally present although often not well developed. When trees are present they usually grow adjacent to the outcrops and frequently shade them. *Ribes roezlii* and *Rhus diversiloba* dominate the shrub layer. Important associates in the herb layer include *G. aparine, Caucalis microcarpa,* and *Bromus rigidus, Phacelia heterophylla, Silene californica, Cheilanthes gracillima,* and *Avena barbata* are the common characteristic species. Notably uncommon on the rock outcrops are the grasses such as *H. lanatus, Agrostis hallii, M. subulata,* and *Trisetum cernuum,* which are abundant in the understory of the open woodlands.

Discussion

The indirect ordination (Fig. 3) resulted in clustering of plots in two dimensional space corresponding to the seven plant community types. The left end of DCA axis-one represents dense stands in mesic locations with less historic grazing disturbance and a lower representation by introduced species. The Ar/Sh type occurs at the far right. These open glades without summer shade sustained the greatest grazing impact. The lower half of DCA axis-2 represents well developed continuous soils. Rock outcrops and rocky stream channels occur at the top of the ordination. The Qu/De occurs on rocky soils and appears intermediate between the types characteristic of outcrops and well developed soils.

Oak/grassland mosaic. The distinctive oak/grassland mosaic characteristic of the bald hills oak woodlands is best developed in the southeast corner of RNP. This pattern occurs primarily on higher ridges, but is continuous downslope on earthflows with southern exposures. Mid-slope oak woodlands are extensive and associated with occasional glades and a large central open prairie. At low elevations and closer to the coast, the prairie becomes the primary feature, with *Q. garryana* stands restricted to forest margins and narrow projections into the grasslands. Oak woodlands extend downslope to Redwood Creek at elevations of less than 100 m in several locations. In mesic low elevation and coastal areas within the fog zone, *P. menziesii* forest has colonized former oak woodlands during the past 130 years. Low elevation stream channels and rock outcrops are converted completely to this conifer forest, and only the open woodlands are left intact. The remaining outcrops and streamside vegetation occur only at mid- to upper elevations in the study area. The remaining open woodlands are the Qu/Da type that is correlated with the mesic nature of the concave lower slopes within the fog belt.

Open woodlands. The Qu/Da, Qu/Sy, and Qu/Cy types comprise most of the area within the well developed open woodlands. Distribution of these three types is related to topography, slope position, grazing, and fire history. Qu/Da and Qu/Sy are found exclusively under closed-canopy oak stands on lower slopes and mid- to upper north-facing slopes. Aspect, sheltered topography, and frequent summer fog make these relatively mesic sites. The Qu/Da type is predominant on the lower slopes under stands of 70–100 yr-old oaks. Qu/Sy occurs under very dense stands of small-diameter oaks on upper north-facing slopes. These stands originated following a fire in 1948 (Sugihara et al. 1983). The two mesic woodland types are closely related floristically. Qu/Sy is probably a fire sere of Qu/Da. Qu/Sy is clearly distinguished from Qu/Da by the dense *S. rivularis*-dominated shrub layer characteristic of the Qu/Sy type. The third major woodland type, Qu/Cy, is found in oak stands composed of all size classes but dominated by widely-spaced, large-diameter trees. This association is found on upper, convex, south-facing slopes and along the ridgeline where moisture conditions are more xeric and grazing was the most intense.

Specialized habitats. The remaining four plant community types are confined to specialized habitats within the study area. Ar/Sh occurs in glades among the oak stands and includes many species characteristic of the continuous open grassland adjacent to the study area. These include weedy introduced grasses and forbs such as *A. elatius, C. echinatus, A. caryophyllea, Trifolium dubium, Trifolium subterraneum, Linum bienne, H. lanatus, R. acetosella, Plantago lanceolata, Hypochoeris radicata,* and *Pteridium aquilinum* (Hektner et al. 1983). Glades also are related floristically to the xeric Qu/Cy woodland, but not limited to xeric topographic positions within the study area. Qu/De is found on relatively moist concave slopes within xeric Qu/Cy woodlands. Dominance of native forbs, especially *D. trolliifolium,* is especially evident in the early summer when the adjacent Qu/Cy type is dominated by immature grasses. Lack of canopy cover results in dominance by characteristic xeric woodland species in mesic physiognomic positions. Two minor community types are found in areas that have very little soil. The Ph/Cy type occupies incised, boulder-strewn stream channels on upper slopes. The numerous dry, exposed, rock outcrops are occupied by the Ri/Ph type. Both Ph/Cy and Ri/Ph are dominated by tall shrubs that thrive on the bare soil and rock surfaces not covered by a thick herbaceous mat.

Introduced species. Success of introduced species in the seven community types appears to be influenced by past grazing and fire. The most heavily grazed communities are grass-dominated and composed of the highest percentage of introduced species. Only 50%

of the high presence species found in Ar/Sh and 53% in Qu/Cy are native. Qu/De is dominated by native forb species with 68% of the high presence species native. Grazing impact on Qu/De was reduced by the lack of early summer grazing, which was restricted due to the toxicity to cattle of the early season dominant *Delphinium trollifolium*. Mesic woodlands supporting the Qu/Da type had 74% native species. Stream channels and rock outcrops were more protected from grazing because of inaccessibility. This is reflected in the 75% native species for Ri/Ph and 82% for Ph/Cy. The highest representation of native species in any vegetation type was the 85% found in the Qu/Sy community that was recently influenced by fire.

Relationship to other woodlands. Ecologically and floristically, these *Q. garryana* woodlands are more similar to those of the Willamette Valley of interior Oregon than to any other California woodland type. The bald hills oak woodlands, however, are distinct from the interior Oregon woodlands in structure, composition, and their coastal habitat (Thilenius 1968). Shrubs dominate all Willamette Valley plant communities, but in bald hills woodlands only the Qu/Sy type, stream channels, and rock outcrops support well developed shrub layers. In the Willamette Valley and the bald hills, stand structure was determined largely in the past by burning. Savannahs with grassy openings between the individual trees that are characteristic of the Willamette Valley were not typical of woodlands in this area. Historical accounts indicate that *Q. garryana* was well-spaced in the pre-settlement stands of the bald hills, but the canopy was closed and alternated with the grasslands.

Fire and succession. Reduction of fire frequency during post-settlement times has altered succession in both the Willamette Valley and the bald hills. Succession is from oak savannah to oak forest, and then to *Pseudotsuga menziesii* forest in Oregon. In the bald hills, succession is from oak forest to mixed evergreen forest in the xeric interior areas, and to *Sequoia sempervirens/P. menziesii* at low elevation and coastal mesic areas (Sawyer et al. 1977). With the cessation of burning by Native Americans and introduction of wildfire suppression, succession to *P. menziesii* has progressed without natural control. Subsequent succession to *S. sempervirens* is seen in older mesic stands of *P. menziesii*. The absence of redwood forest on potential redwood sites supports archaeological evidence of constantly high fire frequency over several thousand years prior to European settlement.

Although allied more closely to the Willamette Valley woodlands than any California oak type, the bald hills oak woodlands are a unique feature of California's redwood region. The National Park Service has allowed the vegetation of bald hills to develop ungrazed for the first time in over a century. This study provides a description

of existing vegetation patterns in the northern bald hills. This baseline information is essential for the monitoring of vegetational changes occurring in response to management of oak woodlands in Redwood National Park.

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